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EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

C. S. BEALS
Dominion Astronomer
Ottawa

J. A. PEARCE
Dominion Astrophysicist
Victoria, B.C.

A. THOMSON
Controller of the Meteorological Service of Canada, Toronto

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Business correspondence, remittances, should be addressed to J. H. Horning, Treasurer of the Society, 3 Willcoks St. Toronto.

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THE JOURNAL
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THE TIDES AND TIDAL PHENOMENA*

By R. M. PETRIE

AMONG the important and interesting practical effects of the sun and moon upon terrestrial affairs the most fascinating, perhaps, is the response of the oceans and seas to the beckoning of these heavenly bodies. To navigators and seafaring peoples the tides and tidal currents are of prime importance. In the business affairs of port communities even the succession of day and night and the round of the seasons are not of more importance than the tides. From early times maritime folk noted the rise and fall of the waters and recognized a periodicity which sometimes could be correlated with the phases and movements of the moon. Our task tonight will be to describe the astronomical phenomena which give rise to tidal forces and to trace their influences in the actual movements of the waters. Some of the consequences of the expenditure of energy by the tides will be explored in addition to the more immediate considerations.

The ancient knowledge and early ideas about the tides were formalized in 1687 by Sir Isaac Newton who gave the correct explanation of tidal phenomena in general, in terms of his newly discovered law of gravitation. The work of Newton and, following him, Laplace and other investigators, laid the foundation of all theoretical studies of the tides. In fact it is not unfair to say that all our modern theoretical knowledge of tidal phenomena stems from the labours of the two giants, Newton and Laplace. It is only by recognizing that

*A lecture before the Victoria Centre, March 12, 1947.

theory alone cannot predict tidal behaviour, and by branching out into semi-empirical methods that present day success in tide prediction has been achieved.

Tidal phenomena are so varied that it is not possible to describe them in terms applicable to all parts of the world. The waters rise and fall in a way that is often complicated but always fundamentally periodic in character. In many places there are two high tides and two low tides every day—the model semi-diurnal tides. In other ports there is but one high tide and one low tide in each twenty-four hours—the diurnal tides. The tidal oscillations vary in height from place to place and, at one place, from time to time. The successive high and low tides sometimes alternate in amplitude and become equal at certain times.

The height of the tide varies greatly from place to place. Far out in the ocean the water rises and falls about two and one-half feet but as we approach a coast the oscillations increase to six, or even ten,

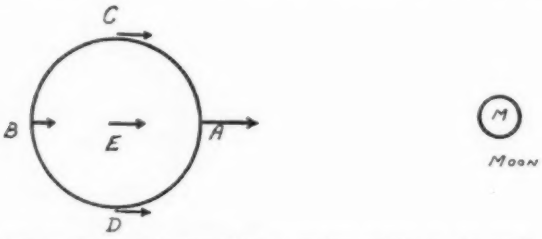

Fig. 1—The moon's attraction at various points on the earth.

feet. In shallow inlets and tidal estuaries and rivers great changes are observed. In the Bay of Fundy tides of fifty feet have been noted and at the entrance to Bristol Channel the range in spring tides is eighteen feet. In the Amazon river a tidal wave runs inland many miles and maintains a height many feet above sea level. These extreme effects are due to the water "piling up" as the channel becomes narrow.

The Tidal Raising Force. To understand the fundamental nature of the tidal force we must go to astronomy and follow the gravitational effects upon the earth, of the moon and sun. Consider for a moment the sketch (figure 1) where the earth is represented as E surrounded

by an ocean and the moon is shown at M. Let the radius of the earth and its mass be the units and the distance of the moon from the earth be R and its mass be M. Then the attraction of the moon at the point A on the earth is given by $\frac{gM}{(R-1)^2}$ where g is the value of gravity at the earth's surface. At E, the earth's centre, the attraction is $\frac{gM}{R^2}$ and at B, directly opposite the moon, it is $\frac{gM}{(R+1)^2}$. At the points C and D (rising and setting moon) the force is essentially the same as at E but it has a component directed inward.

The tide-raising force at any point is the difference between the attraction on the earth as a whole, which is relatively rigid, and that on the water, which is free to move. To a sufficient degree of approx-

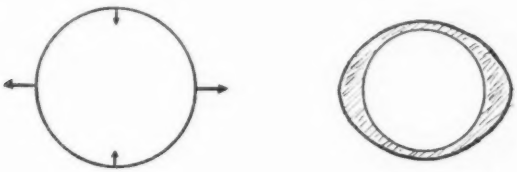

Fig. 2—(a) Resultant tide-raising forces.
(b) Equilibrium form of ocean on a non-rotating earth.

imation it is found that the difference between the forces at A and E is $f = \frac{2gM}{R^3}$. That is, the tide-raising force is directly proportional to the mass, and inversely proportional to the cube of the distance, of the attracting body. If we inspect the resultant tide-raising forces at various points on the earth they are found to be as indicated by the arrows in figure 2 which also shows the equilibrium position reached by an ocean in our idealized model.

The very much simplified model described above does not include any reference to rotation of the earth but we know, of course, that the earth, together with its oceans, is turning rapidly with respect to the movement of the moon. The tidal force at any point on the earth is continually varying due to this rotation and many complications are

introduced thereby. The most obvious result to be noted at this juncture is illustrated in figure 3 showing how the high tide occurs, in general, after the moon has passed the observer's meridian.

It is necessary now to mention some additional factors which contribute to the tide-raising force. First in importance is the solar influence. The sun raises tides in exactly the same manner as the moon but, because of the greater distance of the sun, the solar tides are only some forty percent. as great. When the sun and moon join forces, as at new moon and full, the solar tides reinforce the lunar tides and produce marked "highs" and "lows". These are the *Spring Tides*. When the moon and sun are seen ninety degrees apart in the sky—at first and last quarters—the solar tides tend to neutralize the

Fig. 3—The lag in tides caused by the rotation of the earth.

lunar tides and neither high water nor low water is very extreme. These are the *Neap Tides*.

An important effect is the Diurnal Inequality which is very marked in some parts of Canada's Pacific Coast. When the moon is far north, or south, of the equator, the tidal bulge is not symmetrical and at a latitude of fair distance from the equator only one high tide and one low are observed daily. The effect disappears twice in a lunar month as the moon crosses the celestial equator; it may be seen in some localities in the solar tides.

Other modifying factors may be mentioned very briefly. The varying lunar distance has an effect. At perigee, when the moon is nearest the earth, the lunar tides are thirty percent. greater than those at apogee. The effect of the annual variation in the earth's distance from the sun may be traced in the solar tides, the range from this cause being about six percent. A multitude of secondary effects are

produced by the numerous perturbations of the moon's orbit which change the tide-raising force in various ways and with many different periods.

To illustrate some of the above mentioned features the tides at Victoria, B.C., and Clayoquot, B.C. are shown, for the period March 12-24, 1947, in figure 4.* Victoria is a port in inland waters connected with the ocean by a narrow strait whereas Clayoquot on the west coast of Vancouver Island is more directly related to the open sea.

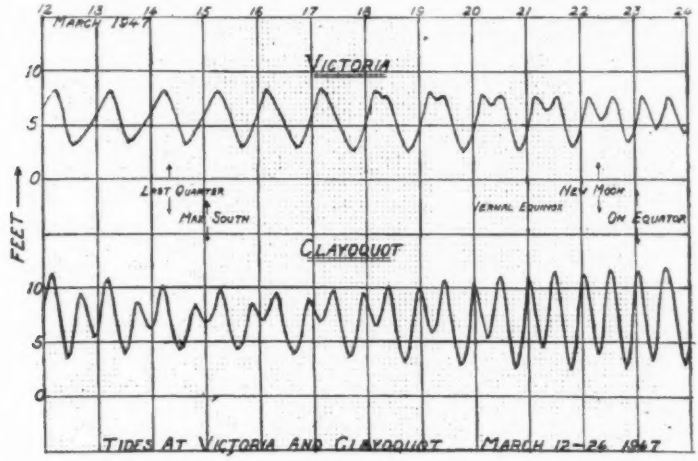

Fig. 4

Note the strong tendency toward diurnal tides at Victoria and the occurrence of the normal semi-diurnal highs and lows at Clayoquot. The neaps and springs may be distinguished by comparing dates near last quarter with those at full moon. The diurnal inequality may be seen if we compare the tides at "maximum south" (March 15) with those "on equator" (March 23).

The Prediction of Tides. The comparison of the tides at Victoria and Clayoquot makes it evident that a general prediction of the tides for even a small region on the earth's surface is impossible except for

*These were made up from *Tide Tables for the Pacific Coast of Canada*, issued by the Hydrographic Map Service.

the vaguest of statements. Two circumstances contribute to this. First the earth, with its oceans and seas, is rotating so that the tidal forces at any point change continuously and the water never reaches equilibrium with the impressed forces. Under these circumstances there is set up in the oceans a state of forced oscillation which is very difficult to follow, theoretically. And secondly, the oceans are contained by irregular land masses and are of varying depth while the coastal waters are shallow and disposed among bays, inlets, and channels, so

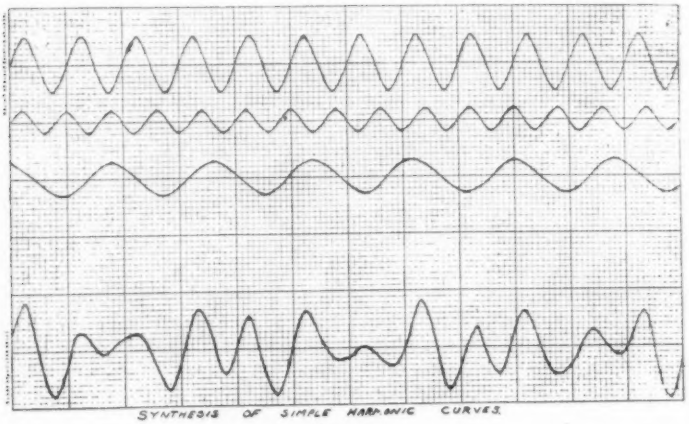

Fig. 5

that it is impossible to apply hydrodynamical theory. However, one very important feature is of substantial assistance; the periods of the various oscillations are constant and known—they are *exactly* the periods of the impressed forces, astronomical in origin, and very accurately known from lunar and planetary studies. We resort, then, to a combination of observation and theory in order to predict the tides. The observations of the tides tell us, upon analysis, the amplitudes and the phases of the various components whose periods are known and they may be segregated and identified by astronomical information. The various oscillations may be added together then for any future time and the resulting tide may be predicted.

The required measurements are made with the aid of a Tide Gauge which gives the height of the water at frequent (e.g. hourly)

intervals. Observations must extend over at least one year before the necessary component variations can be established with reasonable accuracy. All of these components, and there are at least thirty significant ones, are simple harmonic functions. They differ in period and in amplitude and their cumulative effects produce the actual tidal variations. An example of how this happens is shown in figure 5 where three simple harmonic curves (above) are added together to give the apparently irregular and aperiodic variation depicted below.

After the various components have been identified and their amplitudes determined, they may be plotted as far in advance as we like and added together to predict the rise and fall of the sea in the future. The synthesis is performed mechanically by a Tide Predicting Machine which can add together, and give the sum of as many as three dozen separate variations. At the present time machines predict the times and heights of high and low waters for the principal ports of the world.

The success enjoyed by tidal predictions is quite good. Consider the predictions for Portsmouth and Aden as tabulated below. The former port is exposed to irregularities caused by stormy weather while the latter port is affected by the north and south motion of sun and moon.

Portsmouth—(January, May, September, 1897).
In 67% of predictions the time error was less than 10 mins.
In 81% of predictions the time error was less than 15 mins.
In 83% of predictions the height error was less than 1 foot.
Aden—(March, April, November, December, 1884).
In 57% of predictions the time error was less than 10 mins.
In 74% of predictions the time error was less than 15 mins.
In 90% of predictions the height error was less than 3 inches.

Other Tidal Effects. Tidal phenomena are noted in large lakes and land-locked seas. As one would expect from theory the tides are quite small and "follow" the moon (and sun) around the shore-line. At Chicago the range in the tide is a little less than two inches. In the Mediterranean Sea the average tide is about one foot, reaching a maximum of three feet at a few points such as Venice.

A direct measurement of tidal behaviour was made in 1913 by the great experimental physicist, Michelson. A carefully levelled iron

pipe 500 feet in length was half-filled with water and sealed. The height measurements were made with extreme accuracy and tidal ranges of amplitude one-thousandth of an inch were detected. All the usual tidal characteristics were observed in agreement with gravitational theory. An important result of this study was the discovery that the earth itself was deformed by the tidal forces to the amount of thirty percent. of that expected for a fluid body. From this it was calculated that the earth is about as rigid as steel and almost perfectly elastic. The rise and fall of the earth's crust at spring tides is about nine inches!

The idea of generating power from the enormous flow of tidal waters has been proposed, particularly in areas where the more usual sources of hydro-electric power are meagre. In the past tidal currents were used to operate "tide-mills" and some hydro-electric plants have been projected but no large scale development is in use. While not economically practical at present, we must remember that this source of energy is with us and is never-failing.

Astronomical Consequences.

(*a*) Tidal Friction. The tremendous momentum of the ceaseless movement of the water over the ocean floors and against their boundaries generates friction and produces heat energy. Calculations indicate that the dissipation of energy involved is very great, the rate amounting to some two thousand million horsepower. A large part of this dissipation takes place in the Bering Sea where shallow waters and strong currents prevail.

Since the friction is between the earth and its oceans the loss of energy affects the earth's rotation which is retarded. The earth is slowing down and the day is getting longer. How much? At the rate of about one second in one hundred thousand years! Astronomical observations are in general agreement with the above conclusions. Briefly, the evidence is as follows.

(i) The moon is a little ahead of the position it should occupy according to gravitational theory, as shown by observations of occultations. The amount is $4''.3 \pm 0''.7$ per century.

(ii) The sun is a little ahead of the apparent position computed from gravitational theory as shown by records of ancient and modern eclipses. The amount is $1''.5 \pm 0''.3$ per century.

(iii) There is a suspected shortening of the rotation period of Mars, more readily explained as a lengthening of the terrestrial day. The accumulated "error" in the time of any extra-terrestrial event, due to the tidal friction, amounts in one century to about eighteen seconds.

(*b*) Evolution of the Earth-Moon System. The tides produce friction generally because the attraction of the moon tends to cause a "lag" in the waters with respect to the earth's rotation. It may be shown that the reaction tends to accelerate the moon, causing it to move in an orbit continually increasing in distance from the earth. Some day there will no longer be total eclipses of the sun; the moon will be too far from us entirely to cover his fiery disk!

The recession of the moon causes the month to get longer as well as the day, although at a slower rate. The process will continue until the day and month are equal, being each about forty-seven of our present days. The earth and moon will then be in tidal equilibrium with the moon fixed above one hemisphere of the earth and permanent high and low lunar tides. This will not happen for a long, long time; at the present rate of change it will require four hundred billion years.

By reversing our steps we may, in the mind and the realm of mathematics, trace the ancient history of our system to the time when our day was but five hours long and the month only a little longer. The moon was very close then, only some ten thousand miles away. This situation probably existed some four billion years ago.

Turning once more to the remote future we find that the final state is not one of equilibrium. If at that time the oceans are still liquid, and not frozen, solar tidal friction will continue after the moon has come into synchronism with the earth's rotation. The friction of the solar tides in further retarding the earth's rotation will be opposed by the moon which will consequently lose momentum in its orbit and transfer it to the motion of the system about the sun. The moon will then return at last to the earth, but it will be a violent homecoming. Huge internal tides will convulse the earth and the moon will be torn asunder as it approaches closer and closer, while the full extent of the destruction cannot be foretold.

The above is, of course, speculation, but it is speculation based upon the logical development of the consequences of the universal laws of motion and gravitation. While details are blurred the main outlines are founded upon extensive and profound mathematical research. It is marvelous to realize that the gently flowing tides contain the forces which, applied throughout countless ages, ultimately will bring destruction to the moon and visit catastrophe and disaster upon the earth.

Dominion Astrophysical Observatory,
Victoria, B.C.,
March, 1947.

THE ALBERTA TWILIGHT METEOR OF 1946, OCTOBER 21

By William Buscombe

AT 5.32 p.m. Mountain Standard Time on Monday, 1946, October 21, as I was leaving the University Physics Laboratory in Saskatoon, I noticed in the golden twilight to the west over the city a very striking bright meteor. Immediately after taking note of the details of its apparent path, I telephoned to the local newspaper and radio station who graciously brought before the public an appeal for observations from outside points. As soon as the first few letters came in, it was clear that the meteor had fallen over eastern Alberta, so I enlisted the co-operation of Prof. J. W. Campbell of the University of Alberta, who published a statement in the Edmonton daily papers requesting more reports. Several weekly magazines circulating widely among the rural population attracted their readers' interest, bringing a large response. In all, over 130 separate communications were received, but the accounts of only 50 eyewitnesses proved to refer to the twilight meteor in question. All the significant numerical data are abstracted in Table I; a few other people mentioned having seen this meteor without giving precise details. All the places from which it was reported are indicated by dots on the sketch map of the region (figure 1). In most cases the farmers have given their locations quite accurately by quoting their section, township and range numbers in the system of division of land in the prairie provinces.

Weather conditions throughout the prairies were quite favourable to give a clear view of the meteor. A few dissipating patches of stratocumulus cloud at 4-5 thousand feet still remained over a small part of eastern Alberta, according to the official aviation weather observations, and to one or two of my informants who referred their angular estimates on the meteor to the position of these clouds.

Although nearly half of the observers attempted to describe the meteor's colour, they reached no significant agreement, as their impressions seem to have been chiefly psychological reactions to the bright flash in the sky, still in strong twilight for nearly an hour after sunset. Several remarked that this was the first meteor they had ever seen in daylight. By comparison with Venus and bright stars which later appeared, I estimated the meteor as of visual

magnitude −7. Only one observer suggested any sudden change in the meteor's direction of flight, so for simplicity it has been assumed to have fallen in a plane rectilinear path. No detonations or persisting train of light were reported. Several observers were in the fields harvesting and could hear nothing but their tractor or threshing machine engines. One would not expect any meteoric fragments to have survived combustion, unless the object was somewhat brighter and remained visible closer to the earth.

Determination of Path

The lines of sight from each observer to the beginning and end points of the horizontal projection of the meteor's visible path respectively were drawn on working diagrams, and what appeared to be the most probable common points of intersection were chosen, as in the graphical analysis of the detonating fireball of 1946 June 1-2, discussed in a recent Journal. As before, "circles of confusion" were drawn to include most of the intersections of pairs of sight-lines. For the initial point the radius was 17 miles, and for the end point 25 miles, but due to the concentration of observers toward the east-southeast from the meteor's path, it appeared on the diagram that the circle of confusion should be more elliptical, elongated east-southeastward from the end point. The beginning point was graphically determined as longitude 112°22′ ± 18′ West, latitude 53°34′ ± 11′ North, and the end point as 112°58′ ± 30′, 53°27′ ± 15′. It thus appears that the so-called "probable errors" exceed the components of the meteor's visible path in longitude and latitude, so that the direction of approach would be indeterminate, as the horizontal projection of the path was very short.

Accordingly an analytical method was devised to establish the beginning and end points definitely, with their probable errors. On a map of the region drawn on Mercator's projection, the origin of rectangular Cartesian co-ordinates was taken at longitude 106° W, latitude 50° N, with axes Ox westward, Oy northward. For each observing station (x_i, y_i) the equation of a sight-line would be

$$\frac{x - x_i}{y - y_i} = -\tan A_i,$$

where A_i is the azimuth of the beginning or end point as seen from

the station; $x_i = 6(\lambda - 106)°$, $y_i = 6(\phi - 50)°\sec\phi$. Through cross-multiplication the equations assume the form $x + a_i y + b_i = 0$. These were solved by the method of least-squares. The normal equations become

$$nx + y\Sigma a + \Sigma b = 0,$$
$$x\Sigma a + y\Sigma a^2 + \Sigma ab = 0.$$

The solutions are

$$x = \frac{(\Sigma b)(\Sigma a^2) - (\Sigma a)(\Sigma ab)}{(\Sigma a)^2 - n\Sigma a^2},$$

$$y = \frac{n\Sigma ab - (\Sigma a)(\Sigma b)}{(\Sigma a)^2 - n\Sigma a^2},$$

with corresponding probable errors

$$r_x = 0.6745 \left\{ \frac{(\Sigma v^2)(\Sigma a^2)}{(n-2)\left[(\Sigma a)^2 - n\Sigma a^2\right]} \right\}^{\frac{1}{2}},$$

$$r_y = 0.6745 \left\{ \frac{n\Sigma v^2}{(n-2)\left[(\Sigma a)^2 - n\Sigma a^2\right]} \right\}^{\frac{1}{2}},$$

where the residual $v_i = x + a_i y + b_i$, using the calculated values of x and y. The results are as follows:

	Beginning	End Point
x	38.5 ± 0.30	40.8 ± 0.68
y	35.6 ± 0.12	34.2 ± 0.16
λ	$112°25' \pm 3'$	$112°48' \pm 7'$
ϕ	$53°34' \pm 1'$	$53°25' \pm 1'$
No. of Obs.	27	36

This analytical method obviously gives more significant indication of the degree of precision in the computation than the very rough estimate suggested by the circles of confusion. It is interesting that the only previous discussions of probable errors in meteor path determinations which the writer has found in the literature related to teams of skilled observers recording meteors simultaneously from stations separated by 20-50 miles, rather than the chance observations of the general public spread over a wide area. The small

probable errors are a tribute to the accuracy of the observers' estimates. The merit of probable errors is that they may be carried through a computation using the methods of differential calculus, to show the uncertainties associated with derived quantities as well as with direct observational material.

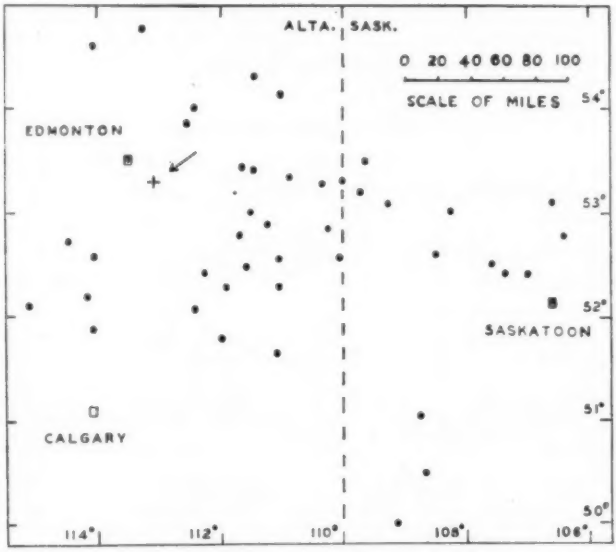

Fig. 1. The meteor was seen from locations marked by dots. Arrow represents visible path; cross indicates earth point.

The length of the horizontal projection of the visible path is found from $L^2 = R^2(\Delta\phi^2 + \Delta\lambda^2 \cos^2 \phi)$ to be $L = 18.9 \pm 5.0$ miles, in azimuth toward S 56°.7 ± 11°.8 W. This path is shown by a very short arrow in figure 1.

Heights

The distances of each observer from the beginning and end points (d_1, d_2 respectively) were measured from an accurate map, and the corresponding heights of the meteor's appearance and disappearance were computed from the approximate formula $H = d \tan h + d^2/2R$,

TABLE I. OBSERVATIONS

Observer and Address	ϕ	λ	A_1	h_1	A_2	h_2	i	D sec.	H_1 mi.	H_2 mi.
William Buscombe, Edwin Brachman, Ruth Murray, Saskatoon	52°08′	106°38′	293	8	290	2	75	2	46	19
R. H. Marshall, Fielding	52 31	107 35	290	12	290	3			52	18
Helene Neal, Maidstone	53 05	109 17	287	30		5		1	80	15
Allen Adair, Athabaska	54 46	113 16	160	18	180	10	10		31	18
G. Coultman, Irma	52 53	111 14	312	30	301	8	60		39	12
Lewis V. Smith, John Bauer, Vermilion	53 21	110 52	280	35	275	15	85	1	47	23
Georg Vanmeer, Amisk	52 33	111 03	320	30	315	10	75		54	18
Mrs. E. G. Bransgrove, Edgerton	52 51	110 15			290					
R. J. Horne, Edmonton (at Dowling Lake)	51 44	111 58	355		335					
Geo. Erickson, T. D. Waite, Ranfurly	53 26	111 32	280	60	270	30			56	32
W. G. Mitchell, Kitscoty	53 17	110 20	287		275	10	55			19
Fred G. Schutz, Iola	52 43	114 28	060	40	060	15	90	2	91	23
Jos. McKone, Edmonton*	53 30	113 30	075	33	105	25	25	5	32	17
Illa McCann, Tangleflags	53 30	109 39	270		270			3		
B. Eymundson, Fawcett	54 36	114 04						2½		
J. M. MacKay, Alliance	52 28	111 35	333	45	295	15	30	4½	85	30
Thos. Thompson, Red Deer	52 11	114 10	040		030	12				23
Margaret MacLaren, Sedgewick	52 47	111 42		30	313	15	45	1½	37	22
Norman Tallon, Blackfoot (at Lloydminster)	53 19	110 00			270		30			
Geo. Trennery, Ponoka	52 39	113 14	025	25	360	20	10	1½	36	20
V. M. Hanson, Eston	51 03	108 46	320	20			50		92	
Servais J. Rahier, Carlton	52 47	106 27	282	12	280	5			62	32
H. R. A. Clark, Bowden	51 52	114 04			025			1½		
John Stanker, Piapot	49 59	109 08			325	5		1		34
Mrs. Harry Hancheruk, Wostok	53 52	112 33	180		205					
Reginald F. Forbes, Hazlet	50 29	108 40			320	5				32
Daniel Svanda, St. Lina	54 19	111 27			225		75	4		
David F. Murray, Castor	52 17	111 54			330	15		2		24
Albert Reimcke, Bentley	52 34	114 03		40	030	20		5	85	29
Mrs. E. A. Smith, Leo	52 04	112 25	360		350	15		5		26
Mrs. Jacob Oster, Hemaruka	51 39	111 05			325	10		10		27

TABLE I (continued)

Mrs. Lula Gunn, Battleford	52	36	108	30	290		290	5		5		21
Alvin S. Cowan, Nevis (at Halkirk)	52	25	112	15	360	50	325	20		1	97	27
E. Harper, Hosclaw	54	09	111	02	230	30		10		2½	41	17
Jas. W. Bolton, Parkside	53	06	106	37			275	7		4		40
Bert Marvin, Dovercourt	52	06	115	08	050	20	050	10	90	10	58	25
J. R. Calhoun, Edmonton (at Reflex Lake)	52	34	110	04			295	5	60			13
Jas. A. Mitchell, Pakan†	54	01	112	26	180		205	15	75	3		12
S. Y. Larson, Airways	52	17	111	03	325		310					

*In house. †On river ferry.

Legend:

ϕ = Latitude north of the equator, λ = Longitude west of Greenwich, A_1 = Azimuth of meteor's first appearance, h_1 = Elevation of first appearance, A_2 = Azimuth of meteor's disappearance, h_2 = Elevation of disappearance, i = Inclination of apparent path to horizon, D = Duration of visibility, H_1 = Computed height of beginning point, H_2 = Height of end point.

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where h is observed elevation and R the earth's radius in miles as in the previous paper. The corrections for refraction on the observed elevations were too small to be taken into account in view of the roughness of the observations, but the effect of the dip of the horizon was considerable in the case of observers nearly 300 miles away. The heights so computed are shown in Table I, columns 10 and 11. For the initial height, the mean of 20 values is $H_1 = 58.4 \pm 3.3$ miles, and from the data of 30 observers the final height is $H_2 = 22.9 \pm 0.83$ miles. Due to the great distances of the observers and their favourable geographic distribution, small shifts in the beginning and end points within their probable errors do not cause any appreciable change in the mean heights.

The true path length visible, computed from $P^2 = L^2 + \Delta H^2$, is $P = 40.2 \pm 5.4$ miles. Note that the probable error of the sum or difference of two quantities m_1, m_2 having probable errors r_1, r_2 respectively, is not $r_1 + r_2$ but $(r_1^2 + r_2^2)^{\frac{1}{2}}$.

The meteor fell with horizontal inclination $I = \sin^{-1}(\Delta H/P) = 62°.0 \pm 26°.2$. As quite a number of the observers mentioned the apparent slope of the meteor's path (Table I, column 8), an independent determination of the true inclination I was attempted,

from the relation tan I = tan i sin Z, where Z is the azimuth difference between the vertical plane of the meteor's fall and the observer's direction. However, the derived values of I ranged almost at random from 0 to 90°, so that no significant result could be obtained in this way to cut down the probable error of the radiant. Clearly it is harder to estimate the slope of a meteor's path than the angular elevations of its beginning and end points, and the associated compass directions.

The earth point, $\lambda' = 113°03' \pm 9'.6$ W, $\phi' = 53°19' \pm 1'.9$ N, is in the immediate neighbourhood of a small lake south of Cooking Lake, about 25 miles southeast of Edmonton, marked by a cross on Fig. 1. The probable errors indicate an even chance that the earth point is inside an ellipse of semi-axes 7 and 2 miles.

Velocity

From 23 observers' estimates of the duration of the flash (Table I, column 9), the mean is taken as 3.3 ± 0.38 seconds, so that the apparent velocity is w = 12.8 ± 3.0 mi./sec. After correcting for the perturbation of the earth's gravitational force, the geocentric velocity is u = 10.8 ± 3.0 mi./sec. As an aid to computers, Axel V. Nielsen of Aarhus, Denmark, has published in Meddedelser Ole Roemer Observatoriet, no. 12 (1938), a table giving in useful form both the perturbation of velocity and the zenith attraction (in this case $\Delta z = +2°.5$), and also the elongation of the radiant from the apex of the earth's way, $e = 125°.3$. Since we had previously $I = 62°$, then the zenith distance of the unperturbed radiant is $\zeta = z + \Delta z = 90° - I + \Delta z = 30°.5$. As the probable errors of these derived quantities grow like a snowball, it seems meaningless to continue to indicate them. For a faster meteor entering the earth's atmosphere more obliquely, they would be relatively much smaller. The heliocentric velocity, from $M^2 = E^2 + u^2 - 2uE \cos e$, is M = 26.2 mi./sec., which is exactly the parabolic velocity of an object revolving about the sun at the earth's distance. The radiant is found to be at Right ascension 340°, Declination 59° N.

Following the steps outlined in Olivier's "Meteors", the elements of the parabolic orbit were computed. They are: q, the perihelion distance, 0.881 astronomical units; i, the inclination of

the meteor's orbit to the ecliptic, 37°; Ω, the longitude of the ascending node, 208°, and π, the longitude of perihelion, 348°.

It is a pleasure to express appreciation for the careful reports sent in by so many observers, for press and radio assistance in drawing attention to the meteor's apparition, and for helpful discussions with the staff of the Dominion Astrophysical Observatory in preparing this paper.

Summary

Time of apparition, 1946 October 21, 5.32 p.m. M.S.T. = Oct. 22.022 U.T.
Appeared at height 94 km. over 112°25′ W, 53°34′ N.
Disappeared at height 37 km. over 112°48′ W, 53°25′ N.
Earth point, 113°03′ W, 53°19′ N; sidereal time, 284°.8.
Length of path (true), 64 km., (projected), 30 km.
Duration of flash, 3.3 seconds; apparent velocity, 21 km./sec.
Slope of path, 62°; from azimuth N 57° E.
Unperturbed radiant, $\alpha = 340°$, $\delta = +59°$.
Geocentric velocity, 17 km./sec.; heliocentric, 42 km./sec.
Parabolic orbit, $i = 37°$, $\Omega = 208°$, $\pi = 348°$, $q = 0.881$.

Department of Mathematics,
University of Saskatchewan,
Saskatoon, August 1947.

JUPITER AND SATELLITES I, II, III AND IV DURING 1948

By Charles E. Apgar

THE following table, in continuation of work published previous years in The Journal, gives the periods during 1948, when Jupiter's satellites will be either all East or all West of Jupiter. The times given are for the 75th meridian (Eastern Standard Time).

1948	All	Begin'g	Durat'n
Jan. 4	West	21h05m	15h04m
14	East	11 28	18 59
19	West	02 43	13 14
20	West	16 08	00 48
26	West	05 30	12 21
28	East	15 27	18 58
Feb. 9	West	11 02	10 36
19	East	00 30	15 48
23	West	16 27	08 59
25	West	01 56	03 47
Mar. 4	East	08 51	11 19
7	East	14 12	05 54
10	West	05 47	05 04
16	West	00 22	06 44
18	East	16 56	07 02
21	East	18 00	10 07
25	East	20 53	04 58
31	West	11 26	07 08
Apr. 4	East	21 43	14 08
9	East	04 32	01 02
13	West	10 26	04 13
14	West	15 08	08 35
26	East	03 11	18 55
28	West	18 45	10 08
May 5	West	20 32	10 57
10	East	06 44	18 56
18	West	22 13	01 53
20	West	00 04	12 36
24	East	10 14	18 57
31	East	11 58	06 54
June 3	West	03 34	14 19
14	East	15 25	18 58
17	West	07 02	15 56
24	West	08 46	16 28
28	East	19 13	18 39
July 8	West	12 16	16 58
12	East	23 02	18 21
22	West	15 49	18 40
Aug. 3	East	06 48	15 58
6	West	05 55	08 31
12	West	21 17	18 59
17	East	12 04	14 24
27	West	01 01	18 58
31	West	17 20	12 53
Sept. 7	East	19 57	12 11
10	West	04 49	18 57
22	East	01 13	10 47
23	East	12 39	01 38
Oct. 1	West	10 39	18 55
7	East	16 29	03 09
15	West	16 54	16 37
19	West	03 36	00 21
20	East	14 55	04 57
27	East	14 18	07 34
30	West	01 33	11 57
Nov. 2	West	07 36	05 00
6	West	05 55	04 57
10	East	19 31	06 22
12	East	02 04	07 18
16	West	11 37	09 46
20	West	14 46	04 36
25	East	00 43	05 12

The following gives the nine periods during 1948 when Jupiter apparently will be attended by only one satellite.

The times given are for 75th meridian (Eastern Standard Time).

1948	Config'n	Begin'g	Durat'n
July 11	4**-O-d	01^h 44^m	01^h 18^m
18	**-O-d4	03 30	00 50
18	*-O-d*4	04 31†	00 49
21	4*-O-dd	16 23	01 39
25	4**-O-d††	05 17	02 22
28	4*-O-dd	18 45	02 05
Aug. 1	**-O-d4	08 30	01 31
4	*-O-dd4	22 19	00 53
8	4**-O-d	12 06	00 06

†III is visible from occultation at 04^h 20^m then eclipsed at 04^h 31^m
††III, II, I disappear within 19^m.

Configurations—
O represents the disc of the planet.
* signifies the satellite is occulted or eclipsed.
d signifies the satellite is on the disc.

549 Carleton Road,
Westfield, N.J.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

Von Humboldt's Account of the Magellanic Clouds

OBSERVERS in the northern hemisphere miss several of the most conspicuous sights in the southern heavens, the two Magellanic Clouds and the dark Coal Sack. The importance of the Magellanic Clouds, as the external galaxies nearest us, has become increasingly apparent in modern astronomy. An excellent historical account of these objects is given by Von Humboldt in his famous *Cosmos,* in which he attempted a description of all natural science. We quote from Sabine's translation, *A Physical Description of the Heavens,* London, 1867, p. 246 et seq.

We have next to speak in greater detail than could be done in the General View of Nature of an object unparalleled in the entire firmament, and which greatly enhances the picturesque beauty, so to speak, of the southern celestial hemisphere. The two Magellanic clouds (which were probably first called by Portuguese and then by Dutch and Danish navigators, *Cape-Clouds**), arrest the attention of the traveller, as I have myself experienced, in the most forcible manner, by their brightness, their remarkable isolated position, and their revolution at unequal distances round the southern pole. That the name which refers to Magellan's voyage of circumnavigation was not their earliest designation is proved by the express mention and description of these luminous clouds by the Florentine, Andrea Corsali, in his voyage to Cochin, and by Petrus Martyr de Anghiera, Secretary to Ferdinand of Arragon, in his work de Rebus Oceanicis et Orbe Novo (Dec. i. lib. ix, p. 96). Both these notices belong to the year 1515, whereas Pigafetta, who accompanied Magellan, does not mention the "nebbiette" in the journal of the voyage previous to January 1521, when the ship Victoria made her way from the Patagonian Strait into the South Pacific Ocean. The older name of "Cape-Clouds" is certainly not to be attributed to the proximity of the still more southern constellation of the Table-Mountain, which was itself only introduced by Lacaille. The name may more probably refer to the real Table-Mountain, and to the phenomenon, long dreaded by seamen as portending tempest, of a small cloud resting on its summit. We shall see presently that the nubeculae of the southern heavens, after having long been noticed but without receiving any name, as navigation extended and commercial routes became more frequented, gradually obtained names derived from those routes.

The frequent navigation of the Indian sea adjacent to the shores of Eastern Africa, especially from the time of the Ptolemies and in the voyages in which

*Lacaille, in the Mém. de l'Acad. année 1755, p. 195.

advantage was taken of the Monsoons, first made navigators acquainted with the constellations near the southern pole. As has been already remarked, it is among the Arabians that we find as early as the middle of the tenth century, a name for the larger of the Magellanic clouds which Ideler has identified with the (white) Ox, el-bakar, of the celebrated astronomer Dervish Abdurrahman Sufi of Rai, a town in the Persian Irak. In the "Introduction to the Knowledge of the Starry Heavens," written at the Court of the Sultans of the Dynasty of the Buyides, he says: "Below the feet of Suhel" (it is expressly the Suhel of Ptolemy, Canopus, which is here meant, although the Arabian astronomers also gave the name of 'Suhel', to several other large stars in the constellation of "el Sefina" or the Ship), "there is a white patch, which is not seen either in Irak," (in the region of Bagdad), "nor in Nedschd," (Nedjed, the northern and more mountainous part of Arabia), "but is seen in southern Tehama, between Mecca and the point of Yemen, along the shore of the Red Sea."* The position of the "White Ox" relatively to Canopus is here assigned with sufficient accuracy for the unassisted eye; for the Right Ascension of Canopus is $6^h\ 20^m$, and the eastern margin of the larger Magellanic cloud is in $6^h\ 0^m$ Right Ascension. The visibility of the nubecula major in northern latitudes cannot have been materially altered since the tenth century by the precession of the equinoxes, for in the course of the next ten centuries it reached its maximum distance from the north. Taking the most recent determination of the place of the larger cloud by Sir John Herschel, we find that in the time of Abdurrahman Sufi it was perfectly visible as far north as 17° N. Lat.; at present it is so nearly to 18°. The nubeculae might therefore have been seen throughout the whole of the south-west of Arabia, the incense-producing country of Hadhramaut, as well as in Yemen, the ancient seat of civilization of Saba and of the early immigration of the Joctanides. The extreme southern point of Arabia, at Aden on the Straits of Bab-el-Mandeb, is in 12° 45′, and Loheia is only in 15° 44′ North Lat. The rise of many Arab settlements on the intertropical east coast of Africa, both north and south of the equator, also naturally led to a more complete and detailed acquaintance with the southern constellations.

Of civilised navigators, the first who visited the West Coast of Africa beyond the Line were Europeans, and first, and more especially, Catalonians and Portuguese. Undoubted documents . . . shew that 178 years before the reputed first discovery of the Cabo Tormentoso (the Cape of Good Hope) by Bartholomew Dias, in the month of May 1487, the triangular configuration of the southern extremity of the African continent was already known. After Gama's expedition, the rapidly increasing importance of the commercial route round the Cape, forming the general object of all voyages along the western coast of Africa, led to the two clouds or nubeculae being called by navigators the "Cape Clouds," as being remarkable celestial phenomena seen in Cape voyages.

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*Ideler, Untersuchungen über den Ursprung und die Bedeutung der Sternnamen, 1809. The name Abdurrahman Sufi is abbreviated by Ulugh Beg from Abdurrahman Ebn-Omar Ebn-Mohammed Ebn-Sahl Abu'l-Hassan el-Sufi el-Razi.

On the east coast of America, the continued attempts to advance southward beyond the equator, and even to the southern extremity of the continent, from the expedition of Alonso de Hojeda, which Amerigo Vespucci accompanied in 1499, to the expedition of Magellan with Sebastian del Cano in 1521, and that of Garcia de Loyasa* with Francisco de Hoces in 1525, had the effect of continually directing the attention of navigators to the southern constellations. According to the journals which we possess, and to the historical testimonies of Anghiera, this was especially the case in the voyage of Amerigo Vespucci and Vicente Yañez Pinzon, in which Cape St. Augustin, in 8° 20′ S. Lat. was discovered. . . . Petrus Martyr de Anghiera, who was personally acquainted with all the discoverers of that remarkable epoch, and whose letters are written under the vivid impression received by him from their narrations, depicts in an unmistakable manner the mild but unequal light of the nubeculae. . . . The great celebrity and long duration of Magellan's voyage of circumnavigation (from August 1519 to September 1522), and the length of time during which the numerous party belonging to it remained under the southern heavens, obscured the remembrance of earlier observation, and the name of "Magellanic clouds" extended itself among the maritime nations bordering on the Mediterranean.

We have taken a single example of the manner in which the extension of the geographical horizon towards the South opened a new field to contemplative astronomy. Navigators advancing under these new heavens felt peculiar interest and curiosity in four objects: the search after a southern pole-star; the form of the Southern Cross, with its upright position when passing the meridian of the place of observation; the Coal-bags; and the revolving luminous clouds. From Pedro de Medina's "Arte de Navegar" which appeared first in 1545, and was translated into many languages, we learn that as early as the first half of the sixteenth century meridian altitudes of the "Cruzero" were employed in determinations of latitude; measurement, therefore, soon followed simple contemplation. The first examination into the position of stars near the Antarctic pole was made by means of distances from known stars whose places had been determined by Tycho Brahe in the Rudolphine Tables: the credit of it belongs, as has been already remarked, to Petrus Theodori of Emden, and Friedrich Houtman of Holland, who sailed over the Indian seas in 1594. The results of their measurements were soon adopted in the star-catalogues and celestial globes of Blaeuw in 1601, Bayer in 1603, and Paul Merula in 1605. These were the feeble commencements of investigations into the topography of the southern heavens previous to Halley (1677) and previous to the meritorious astronomical endeavours of the Jesuit Jean de Fontaney, of Richaud, and of Noël. The histories of astronomy and of geography, in intimate connection with each other, bring before us the same memorable epochs as conducive alike to the completion of the gen-

*The important, and not sufficiently noticed, discovery of the South point of the New Continent, in S. Lat. 55°, belongs to Francisco de Hoces, who commanded one of the ships of Loyasa's Expedition in 1525.

eral cosmical picture of the firmament, and of the outlines of the terrestrial continents.

The two Magellanic clouds, of which the larger covers forty-two and the smaller ten square degrees of the celestial vault, produce at first sight, as seen by the naked eye, the same impression as would be made by two detached bright portions of the Milky Way of corresponding dimensions. In strong moonlight the smaller cloud disappears entirely, while the larger one only loses a considerable portion of its light. The drawing given of them by Sir John Herschel is excellent, and accords perfectly with my most vivid Peruvian recollections. It is to the arduous exertions of the same astronomer at the Cape of Good Hope in 1837, that we owe the first accurate analysis of these wonderful aggregations of the most various elements. He found therein single scattered stars in great number; groups of stars and globular star-clusters; and both regular oval, and irregular amorphous nebulae, more closely crowded than in the nebular zone of Virgo and Coma Berenicis. From the complex character of the nubeculae, therefore, they ought not to be regarded either (as is too often done) as extraordinarily large nebulae, or as detached portions of the Milky Way. In the Milky Way, round star-clusters, and more especially oval nebulae, are extremely rare phaenomena, excepting in a small zone situated between the constellation of Ara and the tail of Scorpio.

The Magellanic clouds are neither connected with each other nor with the Milky Way by any perceptible nebulous appearance. The smaller nubecula is situated in what, excepting the vicinity of the star-cluster in Toucani, is a kind of starless desert; the larger Magellanic cloud is in a less scantily furnished part of the celestial vault. The structure and internal arrangement of the larger nubecula are so complicated, that masses are found in it (like No. 2878 of Herschel's Catalogue), in which the general form and character of the entire cloud are exactly repeated. The conjecture of the meritorious Horner, of the nubeculae having once been parts of the Milky Way, in which their former places can still be recognised, is nothing more than a myth; nor is the assertion of a progressive motion or change of position being perceptible in them from the time of Lacaille, better founded. The indefiniteness of their edges as seen in telescopes of small aperture had caused the positions formerly assigned to them to be inexact, and it has even been remarked by Sir John Herschel that nubecula minor is entered almost one hour in Right Ascension out of its true place in celestial globes and star maps generally. According to the same authority, nubecula minor is situated between the meridians of $0^h\ 28^m$ and $1^h\ 15^m$, and between 162° and 165° north polar distance; and nubecula major in $4^h\ 40^m$—$6^h\ 0^m$ R.A., and 156°—162° N.P.D. Of stars, nebulae, and clusters, he has given in Right Ascension and Declination no fewer than 919 in the larger, and 244 in the smaller nubecula. In order to distinguish the three classes of objects from each other I have counted up in the list:—

In nubecula major, 582 stars, 291 nebulae, 46 star-clusters:
In nubecula minor, 200 stars, 37 nebulae, 7 star-clusters.

The smaller number of nebulae in the nubecula minor is striking; their proportion to the nebulae in nubecula major being as 1:8; while the corresponding ratio of single stars in the two nubeculae is about as 1:3. These tabulated stars, almost eight hundred in number, are mostly of the 7th and 8th magnitudes,—some being between the 9th and 10th. In the midst of the nubecula major there is a nebula noticed as early as by Lacaille, (30 Doradus, Bode, No. 2941 of Sir John Herschel,) which is without a parallel in any part of the heavens. It hardly occupies 1/500th of the area of the entire nubecula, and yet within this space Sir John Herschel has determined the positions of 105 stars from the 14th to the 16th magnitude, which are projected against or detach themselves from the altogether unresolved, uniformly shining, and unchequered nebulous ground.

Opposite to the Magellanic luminous clouds, and at a greater distance from the Southern Celestial Pole, there revolve around it the black spots or patches which at an early period, at the end of the fifteenth and beginning of the sixteenth centuries, attracted the attention of Portuguese and Spanish Navigators. . . . The phenomenon of this class which has been longest known, and which is most striking to the unassisted eye,—viz. the dark patch in the Southern Cross, is situated on the eastern side of that constellation, and is pear-shaped, with a length of 8 and a breadth of 5 degrees. There is in this large space one star visible to the naked eye, (between the 6th and the 7th magnitude), and a large number of telescopic stars from the 11th to the 13th magnitudes. A small group of 40 stars occupies nearly the centre of the space. Paucity of stars and contrast with the surrounding brightness have been assigned as the causes of the sensible blackness of the space in question; and since the time of Lacaille this explanation has been generally received. . . . Whilst I remained under the southern tropic, and under the influence of the powerful impression made upon me by the aspect of the celestial canopy towards which my attention was continually drawn, the above explanation, from the effect of contrast, appeared to me, probably erroneously, to be an unsatisfactory one.

REVIEW OF PUBLICATIONS

Sunspots in Action, by Harlan True Stetson. Pp. 252, 6 x 8½ inches. Ronald, New York, $3.50, 1947.

For over two thousand years there have been references to occasional unusually large sunspots. For two centuries there have been more or less regular telescopic records of sunspots. Only in the past two decades has the close relationship between sunspots and terrestrial atmospheric phenomena assumed a paramount importance in many branches of research.

The radar navigator, the communications engineer and the television operator all find that the conditions of the sun's surface may destroy the quality, or even the feasability of his techniques. He even finds that the astronomers may frequently predict these conditions some days in advance. The meteorologist, with greater or lesser degrees of skepticism or confidence looks for correlation between solar and weather phenomena.

The student of the extenuated upper regions of the atmosphere relates aurorae, temperatures and ionisation to solar conditions. The astronomer tries to analyse the types of radiation and corpuscles arriving from the sun in hope of learning more of the solar properties; and he currently becomes less and less satisfied with the semi-classical picture of the sun, and other stars, as simple spheres of gas in equilibrium. He watches closely for any terrestrial-solar changes that may help to unlock the secrets of the stars or of the interstellar medium. Possibly with an even more desperate curiosity, the economist seek to relate economic cycles, and the biologist life cycles, with cycles of solar activity.

That our knowledge has advanced enough to make many of these fields of definite positive value is due to careful accumulation of statistically enormous quantities of accurate measures of the solar and terrestrial properties involved. One of the most diligent and imaginative scientists contributing to this work has been the astronomer Harlan True Stetson of the Massachusetts Institute of Technology.

In *Sunspots in Action* Professor Stetson has written a book that

will appeal to a very wide circle of general scientific readers. In a systematic way he describes the observational data on a wide variety of solar-terrestrial phenomena: the quantity and quality of solar radiation; the origin and prediction of sunspots; sunspots and radio; terrestrial magnetism and the aurora; and sunspots and the weather, biological and economic cycles.

The quality of the data varies greatly, due in part to the difficulties of the measurements involved, and partly to the foresight of the workers. That some of the radio material is statistically so significant is a tribute to the labours of Professor Stetson himself, and to the great pioneer Sir Edward Appleton, who has supplied this book with an enthusiastic forward.

Some scientists will regard this book as accepting certain relationships which are based on too little exact information; others will consider Professor Stetson as too conservative. The vast majority of readers will find this a very stimulating book, and as a result will take a keener interest in the current very active state of the sun.

The book is illustrated by 42 diagrams and eight plates. One important appendix gives an extensive bibliography of articles ranging from Moon Madness to Forecasting Business Cycles, and from Field Properties of the Developing Frog's Egg to Tropospheric Study of FM Transmission. A second very handy appendix is a table of the Relative Sunspot Numbers, for each month from 1749-1947. This book is nicely printed and substantially bound.

F. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Astronomically Named Chemical Elements

During the past few years nuclear research into the realms of the chemical periodic table have yielded the elements Neptunium and Plutonium. The two radioactive elements are derived from, and lie beyond, the long known radioactive element Uranium.

In selecting names for these elements recourse was had to astronomical analogy. The chemical element Uranium had been discovered in 1789, only eight years after William Herschel's famous discovery of Uranus. The name Uranium was suggested by the chemist Klaproth as a link with Herschel's discovery of the planet. When recently two new "trans-Uranian" elements were discovered, the two "trans-Uranian" planets, Neptune and Pluto, were used for the naming of Neptunium and Plutonium. The still later elements, *Americium* and *Curium* would probably have been named after two new "trans-Plutonian" planets, had astronomers discovered them as a preparation for the naming.

Few people realize, however, how many of the other chemical elements have been similarly named for astronomical objects during the century and a half since the style was set with Uranium. The complete list of such elements would include:

Uranium 1789, Tellurium 1798, Cerium 1803, Palladium 1803, Selenium 1817, Helium 1868, Neptunium 1943, and Plutonium 1943.

A number of these elements in addition to these names have properties of particular astronomical interest.

Uranium, discovered in 1789 by Klaproth, is a very dense radioactive metal. It occurs in pitchblende, particularly in Northern Canada, the Belgian Congo and Bohemia. Its radioactive half-life is very long—4.67 billion years. Astronomically and geologically it is important because its radioactive disintegration into helium and lead permits measurement of the ages of meteorites and terrestrial rocks.

Tellurium, discovered in 1782 by Muller von Reichenstein, was named in 1798 after the Latin *tellus* the *earth* by Klaproth. It is a semi-metallic element of the sulphur group, and is used in ceramics.

Cerium, was discovered in 1803 by Klaproth and by Berzelius and Hisinger. The asteroid Ceres had been discovered in 1801, while the excitement of Herschel's Uranus discovery was still in mind, and before the modern methods showed thousands of asteroids. It was

hence very natural for Klaproth to wish to name the new element after the planetoid Ceres. It is a relatively rare metal used in incandescent gas mantles.

Palladium, discovered in 1803, by Wollaston, was named after the second asteroid, Pallas, which had been discovered in 1802. It is a very stable white metal of the platinum family.

Selenium, discovered in 1817 by the great Swedish chemist Berzelius, was named from the Greek word *selene,* the Moon. It, like Tellurium, is of the sulphur group. Its astronomical interest arises from the fact that its electrical conductivity varies with the brightness of light which falls upon it. Thus it was used as one of the earliest photo-electric light-measuring devices.

Helium, was detected first by Lockyer from the presence of a strong line in the spectrum of the sun at the total solar eclipse of 1868. It was isolated on the earth by Ramsay in 1895. The name *helium* is derived from the Greek *helios,* the *sun,* in honour of its original discovery in the sun. Its use in the radioactive method of age determination of rocks, its widespread occurrence in stellar spectra, and its relatively high astronomical abundance, make it one of the important astronomical elements. It is an inert gas, terrestrially important as the second lightest element.

Neptunium and *Plutonium,* are of currently little direct astronomical importance; being very unstable highly radioactive elements of great density, the chance of their occurrence in significant amounts, or their detection from the earth, is small.

In addition to these eight elements directly named for astronomical objects, there are, of course, many other chemical elements named after the same mythological or geographical sources as certain asteroids. These include:

Columbium	1801	Asteroid	(327)	Columbia	(America)
Europium	1901	"	(52)	Europa	(Europe)
Gallium	1875	"	(148)	Gallia	(France)
Germanium	1886	"	(241)	Germania	(Germany)
Hafnium	1922	"	(362)	Havnia	(Copenhagen)
Holmium	1879	"	(378)	Holmia	(Stockholm)
Polonium	1898	"	(1112)	Polonia	(Poland)
Ruthenium	1844	"	(232)	Russia	(Russia)
Scandium	1879	"	(460)	Scania	(Scandinavia)
Thulium	1879	"	(279)	Thule	(Northland)
Titanium	1791	"	(593)	Titania	(Titan)
		Sat. of Saturn		Titan	
Vanadium	1929	Asteroid	(240)	Vanadis	(Vanadis)
Virginium	1929	"	(50)	Virginia	(Virginia)

F. S. H.

MEETINGS OF THE SOCIETY

MEMBERS ELECTED OCTOBER 20, 1947

Members unattached to Centres, elected October 20, 1947:

Barsona, Vincent . . .	St. Quentin, N.B.
Boyd, Jr., Thomas J. . .	"The Village," Huntington, Penna.
Brown, George	Campbell River, B.C.
Cain, Cleon V.	2215½ 31st Ave. S., Minneapolis 6, Minn.
Campbell, Wm. J. . . .	c/o No. 2 Fire Hall, Lethbridge, Alta.
Carey, John P.	2510 Warring St., Berkeley, Calif.
Chapman, Warner . . .	Weather Bureau, Barrow, Fairbanks, Alaska
Clough, Frank E. . . .	P.O. Box 126, Bellefontaine, Ohio
Cuff, Harry G.	Hammonton, Calif., U.S.A.
Dow, Donald R. B. . .	3137—19th Ave. S., Minneapolis, Minn.
Downs, Hugh M. . . .	1644 Farwell Ave., Chicago, Ill.
Drolet, Raymond . . .	Sacred Heart University, West Bathurst, N.B.
Eckrenrode, Harry L. .	516 Northampton St., Easton, Penna.
Fitzgerald, A. P . . .	17 Finaghy Park N., Belfast, Northern Ireland
Frank, B. R.	Rutland, Vermont, U.S.A.
Garstang, Roy Henry .	129 Duke St., Southport, Lancs., England
Gavenas, Wm. A. . .	Box 119—R D 2 Park St., Dallas, Pa.
Gehring, Harry R. . . .	352 Ridgewood Ave., West View, Pittsburgh 29, Pa.
Gilbert, Walter	2220 N. Quantico St., Arlington, Va.
Hisse, W. H.	P.O. Box 146, Tacoma 9, Wash.
Houston, Walter S. . .	1542 St. Leger Place, Cincinnati 7, Ohio
Hull, Donald B. . . .	88 W. Ridgewood Ave., Ridgewood, N.J.
Jones, Ann Kinder . . .	Warm Springs Foundation, Georgia
Jones, W. H.	85 Columbus Ave., Meriden, Conn.
Jones, A. F.	40 Trafalgar St., Timaru, Canterbury, New Zealand
Law, Ray L.	142 Wildwood Ave., Piedmont, Calif.
Lever, Wm.	586 13th St., San Pedro, Calif.
Mason, G. M.	1 Radin Rd. W., Arvida, P.Q.
Matthew, E. C. . . .	Albertville, Ala.
McAllister, R. D. . . .	Box 399, Rossland, B.C.
Mejia, Petronio	Patio Hincado No. 36B, Trujillo City, Dom. Rep.
Moore, Geo.	314 North McCadden Place, Los Angeles 4, Calif.
Mossman, Fred. A. . .	120 East Pontiac 5 St., Fort Wayne, Ind.
Muses, C. A.	37-16 92nd St., Jackson Heights, L.I., N.Y.
Mussell, Howard J. . .	206 E. Hermosa St., Santa Maria, Calif.
Nathan, Charles C. . .	University of Pittsburgh, Penna.
Parks, A. M.	6400 S. Normal, Chicago 21, Ill.
Paul, Geo. A., M.D.	788 Lyons Ave , Irvington, N.J.

Peterson, J. F.	P.O. Box 1689, McAllen, Texas
Rabedeau, Ronald . . .	2410 Buchanan Rd., Kenosha, Wisc.
Rae, Orville S.	Westcreek, Colo.
Richerson, Floyd . . .	Rt. 1, Box 362A., Denison, Texas
Schutt, Paul L.	1215 Elm St., Glenview, Ill.
Shonk, C. E.	Bucknell University, Lewisburg, Penna.
Wolfe, Gerald R. . . .	8 Shannon St., Middleburg, Vt.
Wootan, Jr., W. O. . .	4731 Stockton Ave., Richmond, Calif.
Zerbee, L. J.	Bellefontaine, Ohio.

AT WINNIPEG

October 15, 1947—A meeting of the Winnipeg Centre was held in Theatre "B" of the University of Manitoba on Wednesday October 15th. Mr. L. W. Koser gave a short talk on "Astronomy in the News".

The speaker of the evening was Mr. W. C. Fisher, Sales Engineer for R.C.A. He gave an excellent lecture showing the close relationship existing between the study of electronics and astronomy. He traced the history of radio and electronics showing the difference between navigation by radio and astronomical methods. Mr. Fisher explained the principle of the sniperscope used in the war by which a gunner can see the enemy in total darkness. He explained the principle of radar and told of its use in the observation of meteors since the war. The members had an opportunity after the lecture of seeing a radar sending and receiving set. Mr. Fisher also had a cathode ray oscilliscope set up on the desk showing the use of the tube in the radar receivers.

C. G. CARD, *Recorder*.

AT OTTAWA

January 30, 1947—A meeting of the Ottawa Centre of the Royal Astronomical Society of Canada was held in the Lecture Hall of the Victoria Memorial Museum at 8.15 p.m., Thursday, 30th January, 1947, with the president in the chair. The speaker of the evening was Wing Commander K. C. Maclure, B.Sc., of Air Force Headquarters. In his introductory remarks, the chairman said that Wing Commander Maclure graduated in Mathematics and Physics from McGill University in 1934, being awarded the Anne Molson gold medal for Mathematics and Natural Philosophy. From university he went into actuarial work, becoming an associate of the Actuarial Society of America. In 1939 he joined the R.C.A.F. as a navigation instructor, and by 1944 had become a member of the navigation research staff at the Empire Air Navigation School in England. Last fall his researches into polar flying were recognized by his being the recipient of the first Colonel Thomas L. Thurlow Navigation Award in Washington. He is now in charge of research into special projects for the R.C.A.F.

Wing Commander Maclure commenced by saying that in the light of the large number of air tragedies of the last few days, he took particular pleasure in announcing the honourable retirement of one aircraft, its only fault being old age.

The R.A.F. Lancaster bomber "Aries," with many thousands of hours to her credit and having winged her way without mishap to all quarters of the globe, was finally to be dismantled. Her last act was to go on display in London as part of a fund raising campaign.

Interest in polar navigation developed soon after Wing Commander Maclure joined the Air Force, largely as the result of his writing of a paper advocating the use of the "G" system of measuring one's direction. This interest reached its fulfilment when, with red tape properly penetrated, the polar flights of the "Aries" were sanctioned. The take-off was from Ireland, where trial flights had been conducted. The polar flights proved the soundness of the navigational theories, and subsequently both the north magnetic and the north geographic poles were circled.

The most uncertain element of these trips was the weather, yet, in spite of the scarcity of weather stations north of the Arctic Circle, the meteorological men did a fine job. Generally speaking there was greater cloudiness than had been forecast, but even so several interesting pictures were taken of the northern wastes from an altitude of about 12,000 feet. On one crossing of Greenland an interesting profile was obtained by means of the radar altimeter. Unfortunately other profiles were unobtainable because the radar altimeter was not functioning at the time of crossing. When the North Geographic Pole was actually circled for the first time, one man threw out the Union Jack while another ate a banana he had scrounged and hoarded for the occasion. The best indications of the magnetic compasses seemed to bear out the predictions of the Astronomer Royal that the North Magnetic Pole was some few hundred miles north-west of its stated position.

In concluding the lecture Wing Commander Maclure recalled that while travelling in England after the polar flights he had overheard an Englishman blame the increasing severity of the English winters on the fact that the scientists aboard the "Aries" had found that the North Pole had moved some five hundred miles closer to England!

February 13, 1947—A meeting of the Ottawa Centre of the Royal Astronomical Society of Canada was held in the Lecture Hall of the Victoria Memorial Museum at 8.15 p.m., Thursday, 13th February, 1947, with the president in the chair. The speaker of the evening, Professor F. S. Hogg, Ph.D., head of the Department of Astronomy at the University of Toronto and Director of the David Dunlap Observatory, gave an illustrated lecture entitled "Our Turbulent Universe".

Dr. Hogg opened the lecture with a review of the work of such pioneers as Hooke, Halley and Herschel in the field of stellar motions. With the aid of slides he explained that the apparently random motions of the stars are the result partly of their own proper motions and that of the sun through space. In general, all stars of the galaxy rotate about a common centre; our sun, which is located approximately two-thirds of the galaxy's radius from its centre, completes one revolution about this common centre in approximately 200,000,000 years.

Turning to the field of stellar dynamics, Dr. Hogg emphasized the importance of double stars in estimating a star's physical characteristics. By applying the laws of motion, which he demonstrated with the aid of a tennis ball and some lengths of elastic, to a double star of known period it is possible to determine the masses of its components. In addition eclipsing doubles furnish information on a component's diameter, this together with its mass gives its density. Spectrographic observations give us the star's luminosity or energy output. Observations of double stars have shown that there is a fixed relationship between a star's mass, luminosity, and density; these relationships, as shown in the Mass-Luminosity Table, make it possible to determine the mass and density of any star once its luminosity has been obtained by spectrographic observation.

Studies of the motions of star clusters such as the Pleiades indicates that these clusters are breaking up and have not existed as clusters for more than 5,000,000,000 years. Since no new clusters are being formed it is safe to assume that the clusters were formed at the same time as the Galaxy. Studies of radioactive disintegration in terrestrial rocks indicate that these rocks solidified 3,000,000,000 years ago. Allowing one or two billion years for these rocks to cool to a solid state, it seems evident that the earth came into existence as a separate body at the same time as, or shortly after, the formation of the Galaxy.

February 27, 1947—A meeting of the Ottawa Centre of the Royal Astronomical Society of Canada was held in the Lecture Hall of the Victoria Memorial Memorial Museum at 8.15 p.m., Thursday, 27th February, 1947, with the president in the chair. The guest speaker, Mr. W. H. Stilwell, M.A., of the Division of Geodetic Astronomy and Isostasy, Geodetic Service of Canada, gave an illustrated lecture entitled "Mapping Our Northland".

Mr. Stillwell opened his lecture with a brief description of the methods used in mapping the largely uninhabited north country. Topographic maps are largely drawn from trimetrigon photographs taken at an altitude of 20,000 feet, and it is necessary for ground parties to determine the exact position of specific points on these photographs from astronomical observations made with theodolites. Due to the inaccessibility of many of these points these ground parties are usually flown in. Mr. Stilwell then showed slides taken during a surveying expedition. Two planes were used, a twin-engined Canso amphibian and a single-engined Norseman floatplane, the Canso being used to supply base camps while the Norseman took individual survey parties to various points.

The slides graphically illustrated the rocky, lake-ridden nature of the country and the difficulties of landing and beaching aircraft in the small, shoal-filled lakes. Moss is the principal vegetation in this barren land, forming a blanket from eight to twelve inches thick which acts as an insulator for the permanently frozen mud or permafrost which plagues builders in the north. If there is a lack of vegetation on the land, there is apparently no lack of fish in the streams and lakes, as one series of slides aptly demonstrated. Other slides dealt with the natives of the region and the activities of the members of the expedition.

It had been hoped to show a film on aerial mapping entitled "Photo Canada" at the conclusion of the lecture, but due to unforeseen delays the film was not available in time.

March 13, 1947—A meeting of the Ottawa Centre of the Royal Astronomical Society of Canada was held in the Lecture Hall of the Victoria Memorial Museum at 8.15 p.m., Thursday, 13th March, 1947, with the president in the chair. The speaker of the evening, Mr. J. Dainty, of the Atomic Research Division, Chalk River, gave an illustrated lecture entitled "Atomic Energy and Stellar Evolution".

Mr. Dainty opened the lecture with slides and a description of the pleasant modern community of Deep River, which houses the workers of the Atomic Research Division at Chalk River.

After describing the internal structure of atoms and the properties of sub-atomic particles, Mr. Dainty explained the cycle reaction which, using hydrogen as fuel and carbon as a catalyst, is the source of energy in main sequence stars. As this cycle reaction progresses, a main sequence star tends to become hotter, larger, and more luminous until its hydrogen is used up. Then the reaction ceases and, as the star's internal pressure can no longer withstand its gravitational force, it slowly begins to contract, this contraction resulting in a further production of energy.

In white dwarf stars, contraction has progressed to such an extent that atoms and sub-atomic particles are compressed to an unbelievable density. According to one theory, a white dwarf will eventually reach a stage where electrons will be driven into the nuclei of the atoms: when this occurs, the tremendous heat evolved will result in the explosion of the star into a supernova.

As for the third class of stars, the red giants, a recently expounded theory divides them into pre-main sequence and post-main sequence classes. In the first stage of the evolution of the pre-main sequence red giants, the star's deuterium (heavy hydrogen) is used up. This is followed by the utilization of the star's lithium, boron and beryllium, in that order. After a relatively brief period as a pulsating or variable star, the young red giant develops into a typical main sequence star.

In the post-main sequence red giant, nearing the end of its career with the final depletion of its hydrogen, the cycle reaction previously described tends to take place not in the nucleus but in the gaseous envelope of the star, resulting in a star with a dense core and an extensive, tenuous atmosphere. After this atmospheric cycle reaction has ceased the atmosphere contracts into the core and the star ends its career as a typical white dwarf.

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